TD505A

Introduction to Shuttle Mission Simulation

Mission Operations Directorate
Space Flight Training Division
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Prepared by

Willis E. Eastabrooks

Willis E. Eastabrooks for Rebecca Hughes, SME
Sim Sup Office

Approved by

Melvin L. Richmond

Melvin L. Richmond
Chief, Systems Training Branch

Mission Operations Directorate
Space Flight Training Division
Systems Training Branch

Technical Support

Document Coordinator

Rebecca Hughes

Computer Complex

Sam Parker

Shuttle Mission Simulation

Caasi Moore

Simulation Control Area

Simulation Supervisor Office

General

Patrick Davis

Foreword

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This material is for training purposes only and should not be used as a source of operational data. All numerical data, displays, and checklist references are intended only as examples. To determine any prerequisites before using this document, consult the applicable Certification Plan. For shuttle manuals, consult the Flight Operations Support Personnel Training Guide (Blue Book) or the Crew Training Catalog. For Space Station manuals, consult the appropriate Space Station Certification Training Guide or Training Administration System (TAS). The applicable training package should be studied before attending any classroom session or lesson for which this is a prerequisite.

A Training Materials Evaluation is included at the end of this document. Inputs on this sheet will be used to evaluate the lesson material. You do not need to sign the sheet.

Preface

This book provides a fundamental description of the shuttle mission simulator (SMS) located at NASA JSC for those who are unfamiliar with this simulator. It contains information concerning the SMS complex, its purpose and capabilities, the support computer facility, and the role of the SMS in integrated simulations. This book should be used as an SMS overview source and not as a detailed textbook. For detailed information concerning the SMS capabilities, refer to the SMS Statement of Work, Addendum A: SMS Design.

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Section 1
Introduction

Overview

The Jake Garn Mission Simulator and Training Facility (JGMSTF), otherwise known as the Shuttle Mission Simulator (SMS), is the prime training facility for crew training in the shuttle program. It is the only high–fidelity simulator facility capable of training flight crews for all phases of a mission, from lift–off minus 30 minutes through rollout. This includes prelaunch checkout, ascent aborts, on–orbit operations (including payload deployment and rendezvous), entry, landing, powerdown, and contingency operations. To support this high–fidelity requirement, the SMS uses real–world flight computers and associated support equipment and flight software, along with flight cockpit hardware (instruments, displays, and controls). In addition, visual, aural, and motion cues are provided by the computer–generated out–the–window scenes, hidden speakers, and a motion platform.

The SMS complex consists of a Fixed–Base Crew Station (FBCS), a Motion–Base Crew Station (MBCS), a Guidance and Navigation Simulator (GNS) crew station, three Instructor Stations (ISs), three Operator Stations (OSs), the Network Simulation System (NSS), the Spacelab Simulator (SLS) and its supporting IS and OS, and the supporting computer facility. The SMS occupies most of the north side of Lyndon B. Johnson Space Center (JSC) building 5N; the two crew stations, their support OSs, and most of the computer complex are located in the high bay area, while the ISs are located in the adjacent low bay area. The GNS is located in building 35. See figures 1–1 and 1–2 for a layout of building 5 and figure 1–3 for a layout of building 35.

Background

In the last 25 years, flight simulation has become the major method of training personnel for commercial, military, and space vehicle operations. Ever since the Mercury Program, flight simulation has proven to be the best and, in most cases, the only practical way to train astronauts for space flights. The SMS, designed for this purpose, is a major milestone in flight simulation sophistication and fidelity.

Constructed in 1976–77, the SMS has been operational since late 1978 and is expected to provide shuttle crew training for the next 30 years. The complex is maintained and operated by the Rockwell Space Operations Company (RSOC), UNISYS, and AlliedSignal Technical Services (ATSC) under the Space Operations Contract, started in 1986. Loral and Rockwell International provide the prime and backup flight software, respectively.

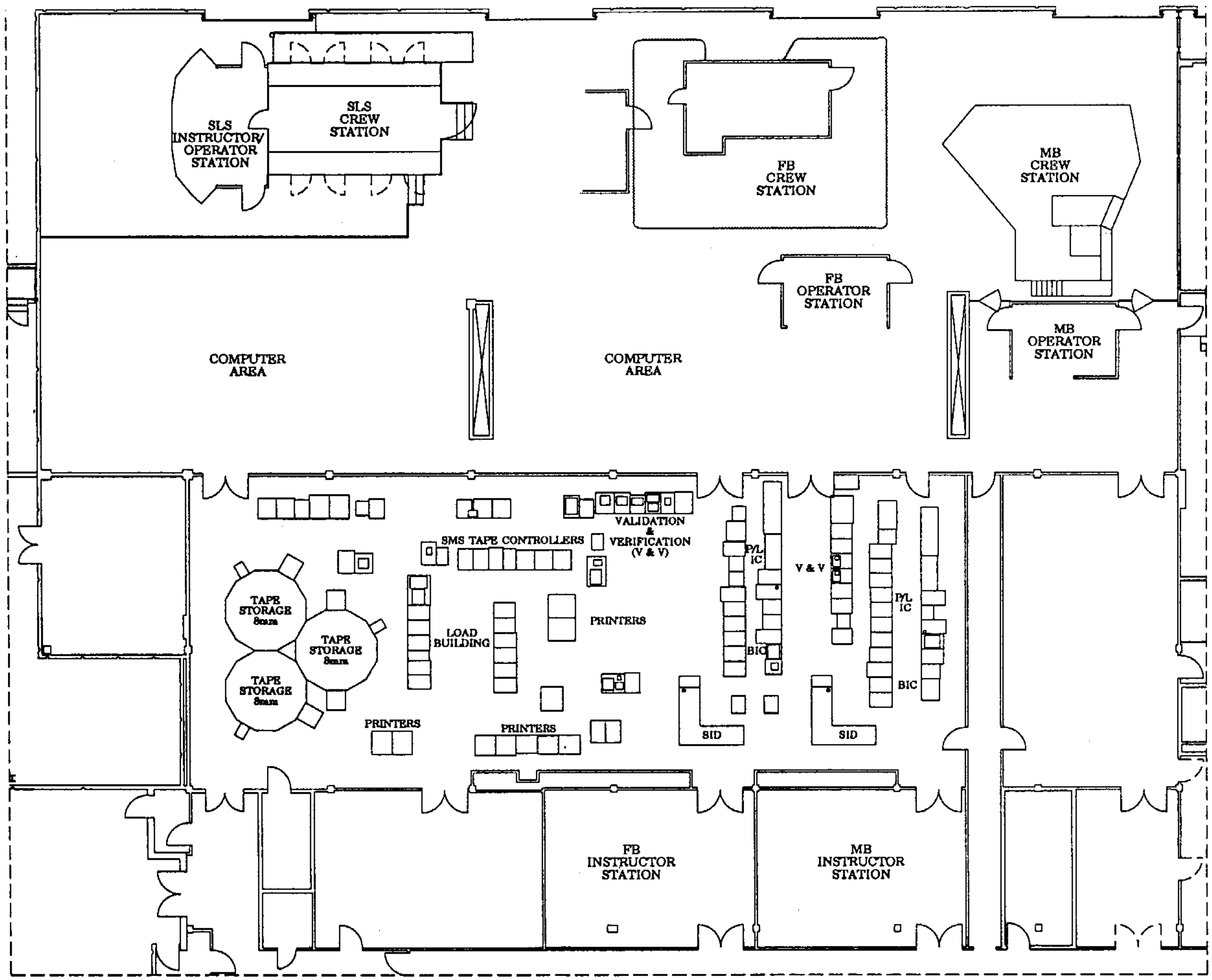

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Figure 1–1. Map A – Building 5 Crew Training Facility, first floor

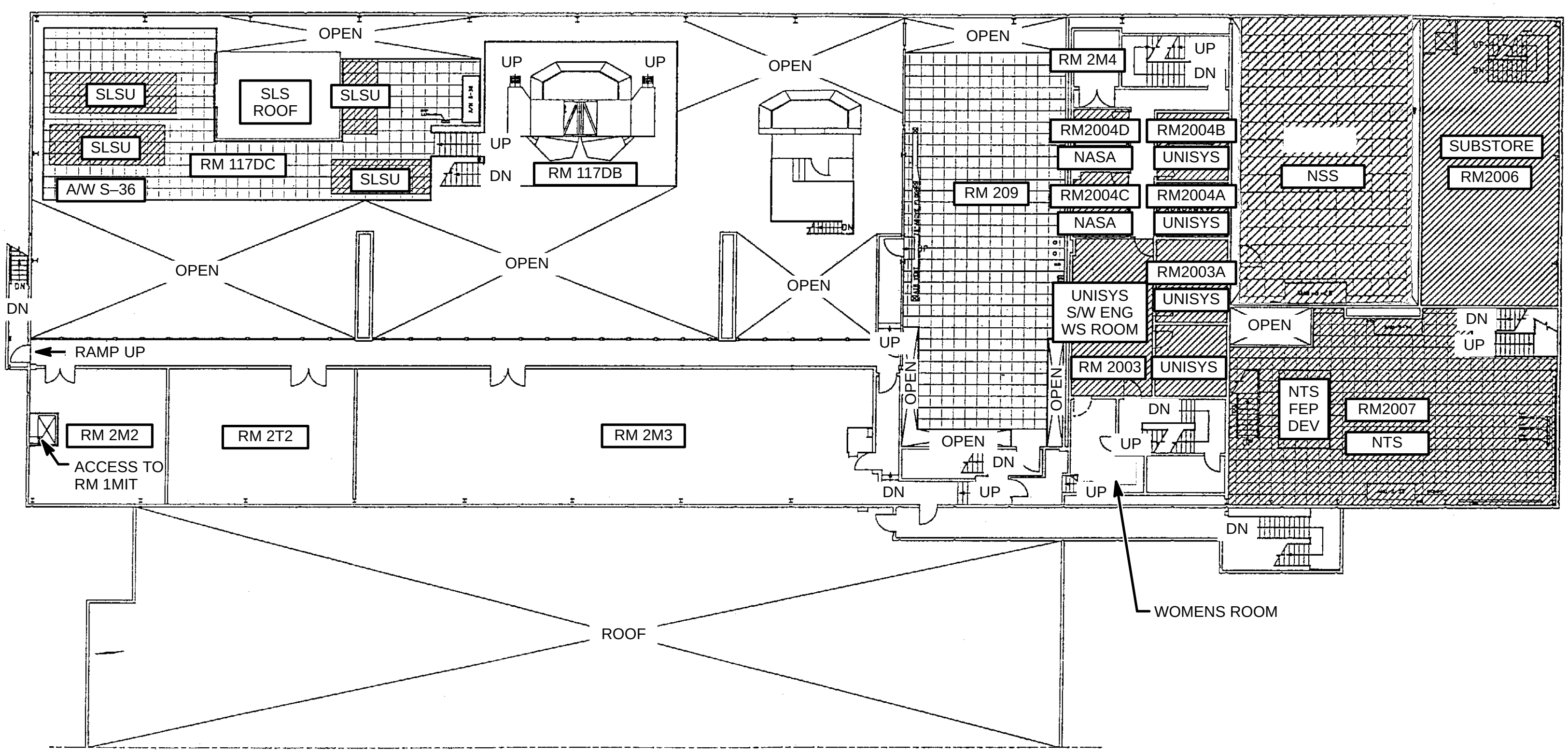

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Figure 1–2. Map B – Building 5 Crew Training Facility, second floor

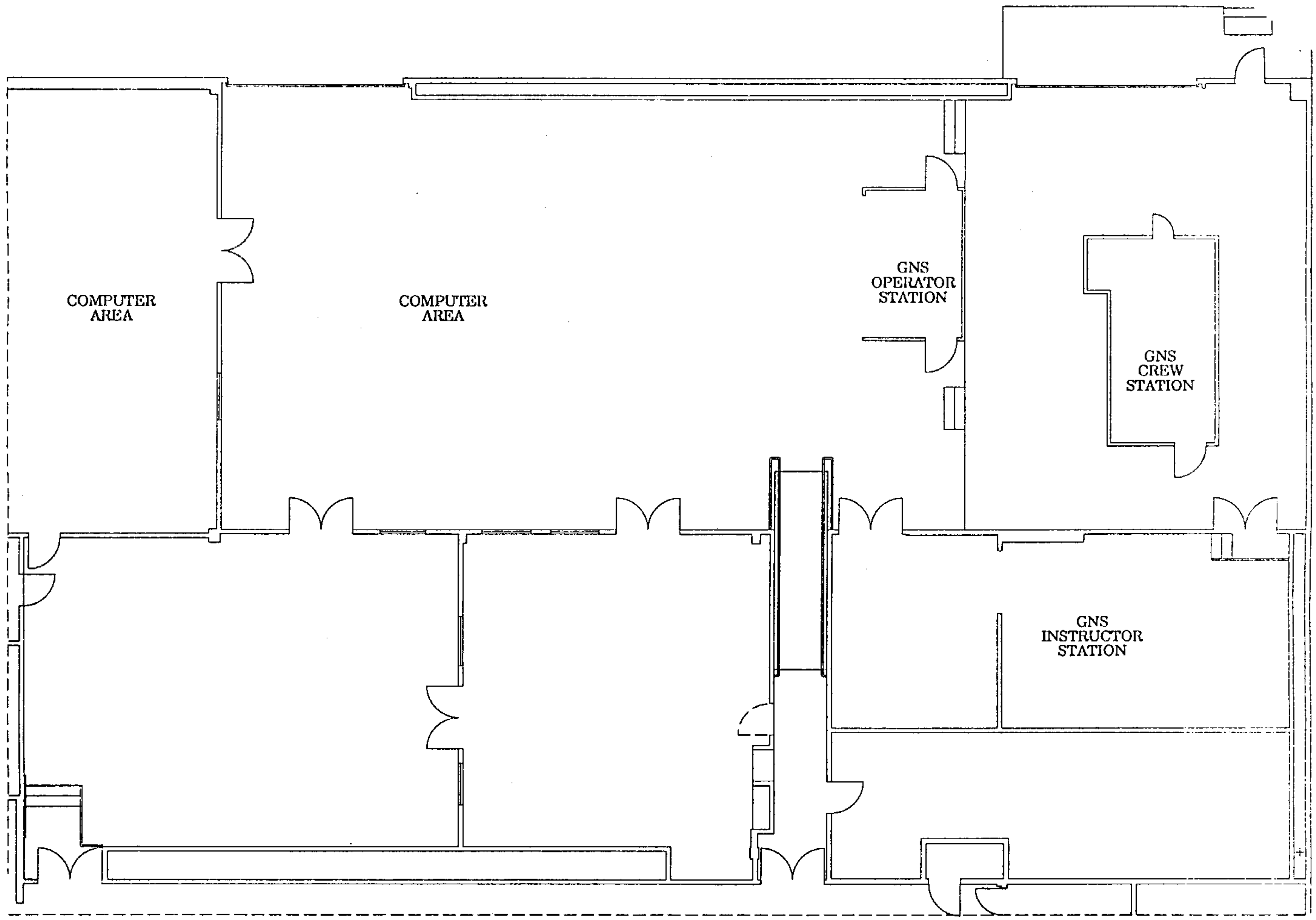

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Figure 1–3. Map C – Building 35 Crew Training Facility

Section 2
SMS Utilization

Purpose

The primary purpose of the SMS is to train flight crews for all their activities in the orbiter flight deck and some of their activities involving the middeck. The SMS is used for the following specific purposes:

a. To train crews for normal and contingency operations in both generic and mission–specific flight procedures

b. To familiarize pilots with the handling characteristics of the vehicle

c. To train mission and payload specialists in payload operations, including use of the Remote Manipulator System (RMS)

d. To support training of all Mission Control Center (MCC) personnel during integrated simulations (figure 2–1)

e. To provide real–time mission support by evaluating anomalies and developing contingency procedures

f. To familiarize crews and instructors with all cockpit hardware of the orbiter flight deck (location and function) and with the various orbiter support and avionics subsystems

g. To enable crews, instructors, and Flight Data File (FDF) personnel to verify flight procedures

h. To verify flight software through normal use of flight General–Purpose Computers (GPCs)

Training Flow

This section outlines the training flow for astronauts from candidates to flight–ready status and describes how the SMS is used in this training.

The astronaut training program begins with a basic training program. Basic training is generic in nature. It familiarizes new personnel with the National Aeronautics and Space Administration (NASA) and the Space Transportation System (STS) and prepares them for further training in individual assignments. After completing basic training (2000 level), the astronauts begin generic shuttle systems training until assignment to a flight. Flight assignment is approximately 12 months before a flight.

Following flight assignment, astronauts are placed in advanced flight–similar and flight–specific training (3000–9000 level). Advanced training provides generic knowledge and skills necessary to perform proficiently on “typical” shuttle flights (figure 2–2). At this time, the astronauts are assigned to a specific training team and training manager.

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Figure 2–1. Mission Control Center

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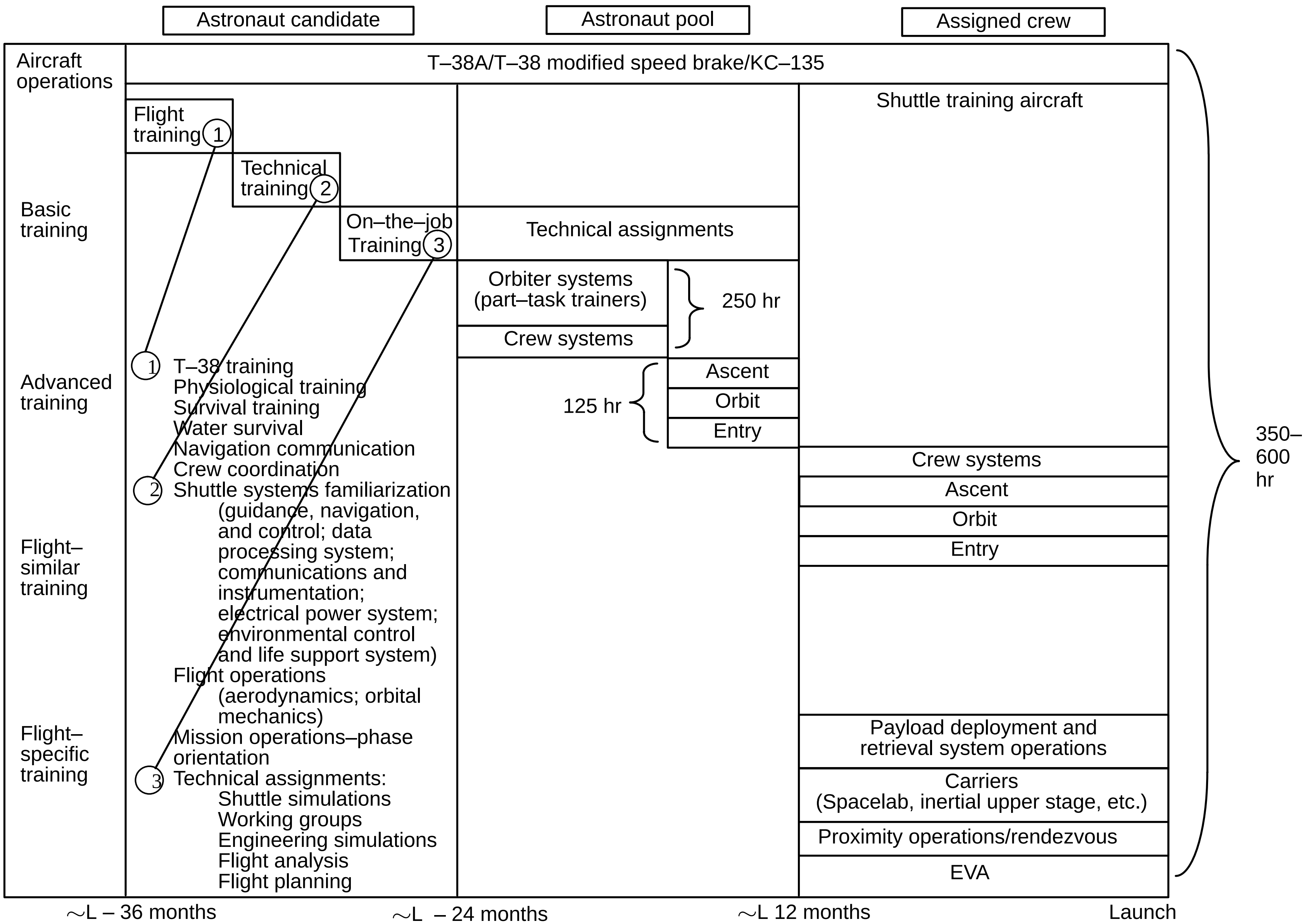

Figure 2–2. Typical pilot astronaut training program

After the flight is completed, the astronauts return to generic training, where proficiency is maintained with a recurring training program (figure 2–3).

The use of the SMS in three of the four training categories (advanced, flight–specific, recurring) is indicative of its essential role in the shuttle training program. Figure 2–4 illustrates the role of the SMS in subject training, and tables 2–1 and 2–2 show candidate and assigned required crew hours, respectively. Table 2–3 gives examples of subjects for which training is provided in the SMS.

Availability

The SMS is operational 24 hours a day. Weekly activity schedules usually call for crew training during the first and second shifts, procedure verification training during the second shift, and SMS maintenance and modification during the third shift and on weekends. (During the long simulations or real–time contingency support, flightcrews may be required to occupy the crew stations for periods of over 24 hours.)

At the present time, the use of the facility by non–JSC organizations is extremely limited because of the heavy training loads associated with the scheduled space shuttle flights. In fact, SMS time for anyone other than crews is very limited, since a crew's training on the SMS starts approximately 11 months before the actual flight.

Fixed–Base and Guidance and Navigation Simulators

The Fixed–Base (FB) simulator and GNS are the most critical parts of the Shuttle Training Program. It is possible to simulate the entire shuttle mission using either of these two simulators. They have the only complete, high–fidelity shuttle cockpits with active controls and displays available for mission training. Figure 2–5 depicts the forward flight deck of the FB simulator. Vehicle controls and displays are accurately simulated in the forward and aft flight decks, and there are some active controls located in the middeck, also. In addition, the simulators are stowed with a subset of the flight crew equipment and FDF procedures. Both simulators seat four crewmembers on the flight deck for ascent and entry operations. Either simulator can also be configured to seat additional crewmembers on the middeck. They are also equipped with a regulated breathing air system to allow crew training in ascent and entry operations using crew escape suits. Outside the FB middeck is the Waste Collection System (WCS) trainer. Both the GNS and FB have active Extravehicular Activity (EVA) equipment that is used during integrated simulations. This EVA equipment allows the EVA crewmembers to operate in building 29 in the WETF during integrated simulations involving EVA's. During simulations in excess of 6 hours in length, food and water are provided for the crew at the GNS or FB to practice meal preparation. In addition, a WCS trainer is located next to the FB in building 5.

The controls and displays provided in the two simulators include simulation of the out–the–window visual scenes and the vehicle aural cues. (Refer to the section on visual and aural simulations for a summary of these capabilities.)

The FB is located in the high bay area of building 5 (see map A, figure 1–1) on an elevated platform (figure 2–6). The GNS is similarly located in building 35. Entrance to either simulator

is through openings in the middeck walls. Access to the flight deck is through the interdeck access hatch from the middeck.

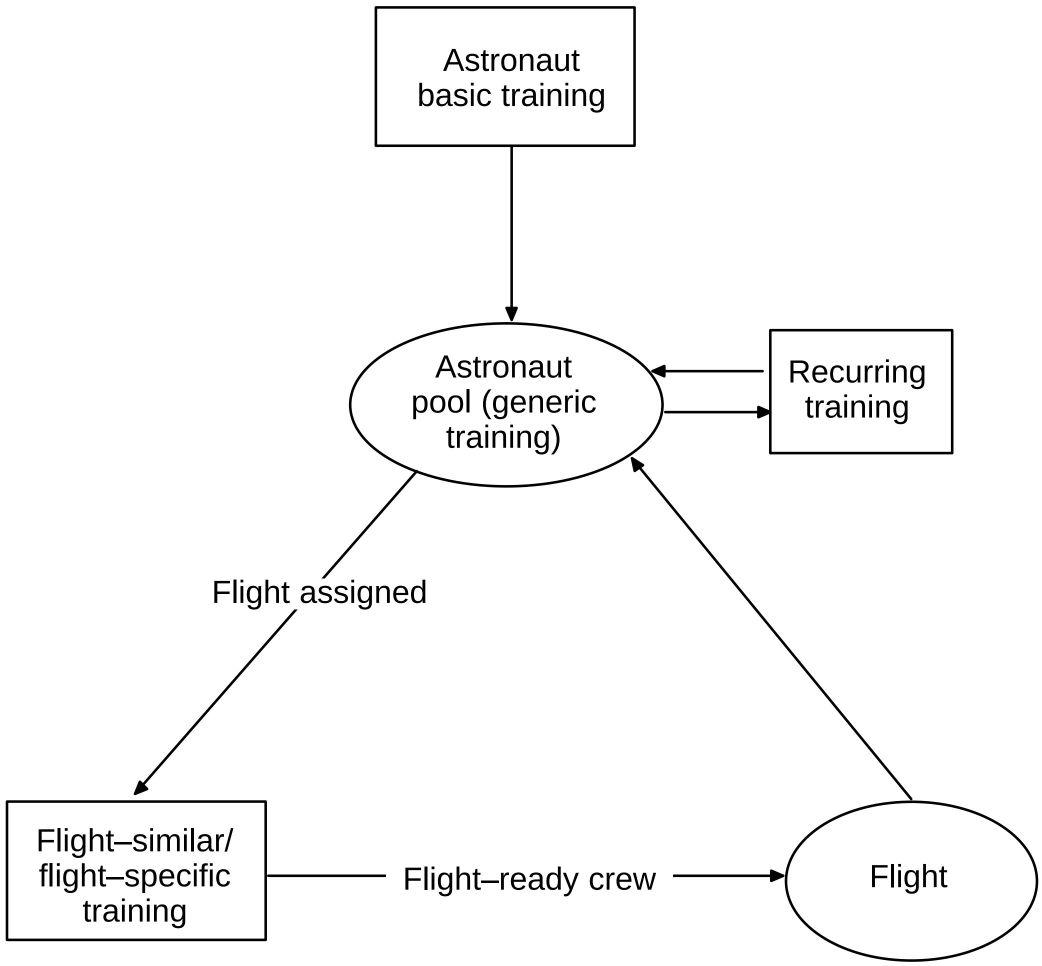

Figure 2–3. Astronaut training flow

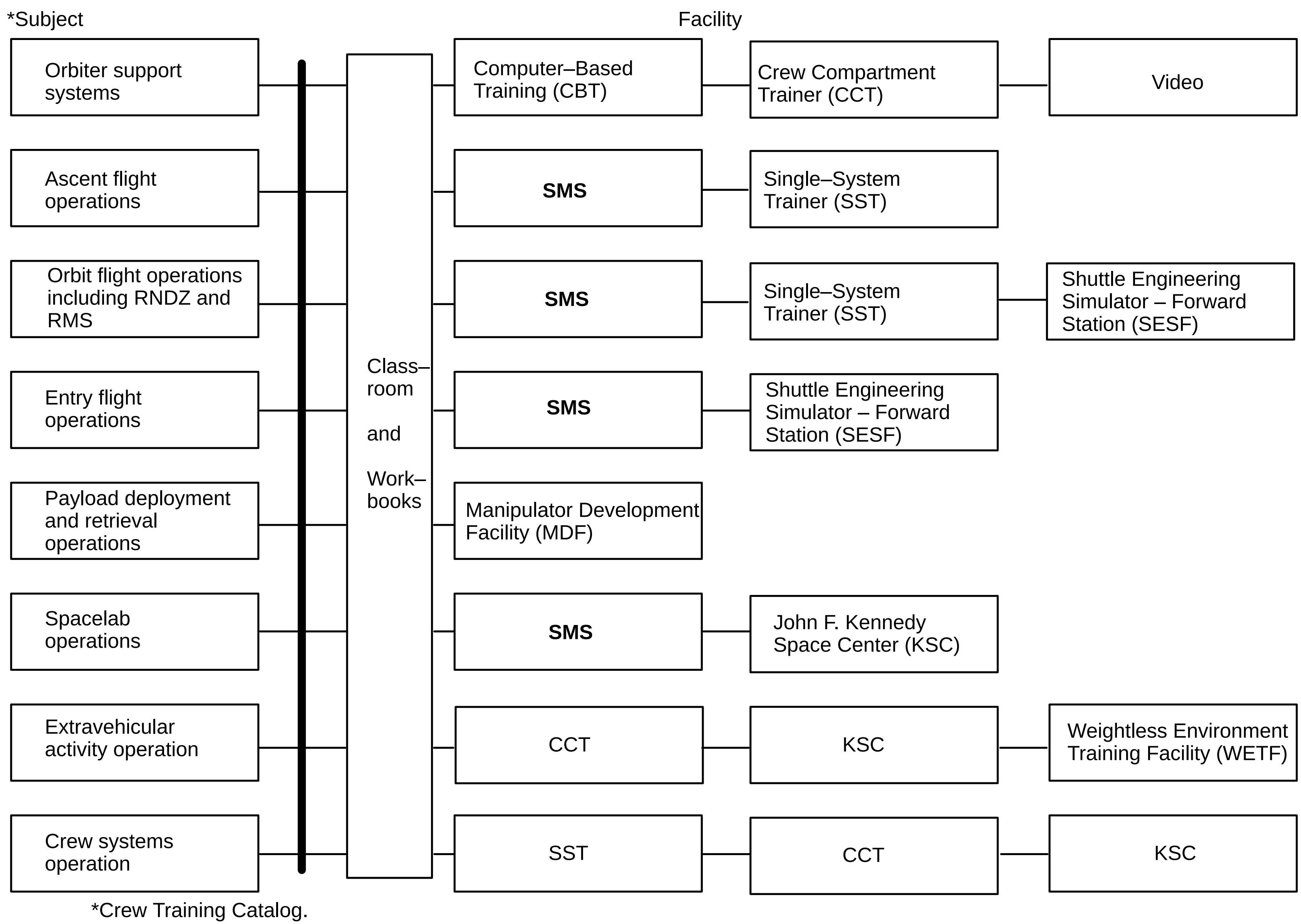

Figure 2–4. Training flow and facility use

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Table 2–1. Candidate astronaut training required hours (2000 level)

Subject	Classroom and workbook	CBT	SST	SMS	CCT	SESF	WETF	Other *
Orbiter systems	179.5	22	81		5.5			0.5
Entry	22.5		4	30				
Deorbit	11	2		15				
Orbit	9.5		2	24				
Ascent	16			24		7.5		
Crew systems	47	1			12		3	1
Payload operations						48		
Deployment and retrieval								
Rendezvous/proximity	44	4	8	12				
Spacelab			106					4
IUS	15		12	13				
Spacehab								
EVA	15	3			6		25	4
Total	359.5	32	213	118	23.5	55.5	28	9.5

* Includes Full Fuselage Trainer (FFT), video, Extravehicular Mobility Unit (EMU) MAL SIM, and payload trainer. Data from Crew Training Catalog.

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Table 2–2. Assigned crew required training hours (3000–9000 level)

Subject	Classroom and workbook	CBT	SST	SMS	CCT	SESF	FFT	WETF	Other *	KSC
Orbiter systems	1	1			2				6	
Entry/deorbit	13			55		9.5				
Orbit	10		6	26						
Ascent	15			62						
Crew systems	12		1		33.5		4			3
Payload operations	66			88	42	85.75	4		30	
Deployment and retrieval	14								44	
Rendezvous/proximity	1		4	117						
Spacelab	4			208						2
IUS	9			4						
Spacehab	6			4					40	
EVA	22				11			147	28	4
Total	173	1	11	564	88.5	95.25	8	147	148	9

* Includes the air–bearing floor, MDF, Spacehab Intelligence Familiarization Trainer (SHIFT), SLS, payload trainer, and Spacehab Payload Processing Facility (SPPF) JSC. Data from Crew Training Catalog.

Table 2–3. Simulated subsystems

- Communications and navaids
  - Caution and warning
  - Ku–band
  - Microwave scanning beam
  - Operational instrumentation
  - Rendezvous radar
  - S–band
  - TACAN/radar altimeter (no atmospheric effects)
  - UHF
  - CCTV
- Computer interface
  - Engine controller interface
  - Formatting
  - Main engine controller
  - Master events controller
- Dynamics
  - Atmospheric drag (below 150 km)
  - Body bending
  - Ephemeris
  - Gravity
  - Ground contact
  - Mass properties
  - Orbiter/target equations
  - Wind (steady, gust, shear, turbulence)
- Electrical power
  - Distribution
  - Fuel cells
  - Reactants storage and distribution
- Environmental control
  - Atmospheric circulation
  - Auxiliary power
  - Freon loops
  - Gas supply
  - Space radiator
  - Vent and purge
  - Water coolant and supply system
  - Pressure control system
- Flight control
  - Automatic
  - Control stick steering
  - Manual direct
- Guidance and control
  - Air data system
  - Body–mounted sensors
  - Controls and displays
  - Star tracker
  - Thrust/surface control
- Measurement processors
  - Flight recorders
  - Network signals
  - Pulse code modulation master unit
  - Timing unit
- Mechanical power
  - Auxiliary power units
  - Hydraulic system
- Mechanical systems
  - Landing and braking
  - Manipulator arm
  - Payload bay doors
  - Separation
  - ET umbilical doors
  - Radiator system
- Propulsion
  - External tank (fuel slosh)
  - Main engines
  - Orbital maneuvering
  - Reaction control (no plume impingement effects)
  - Solid rocket boosters
  - Thrust controller
  - Valves and supply tanks
- Tracking network
  - Voice communication
  - Telemetry
  - Tracking

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Figure 2–5. Forward flight deck of the fixed–base simulator

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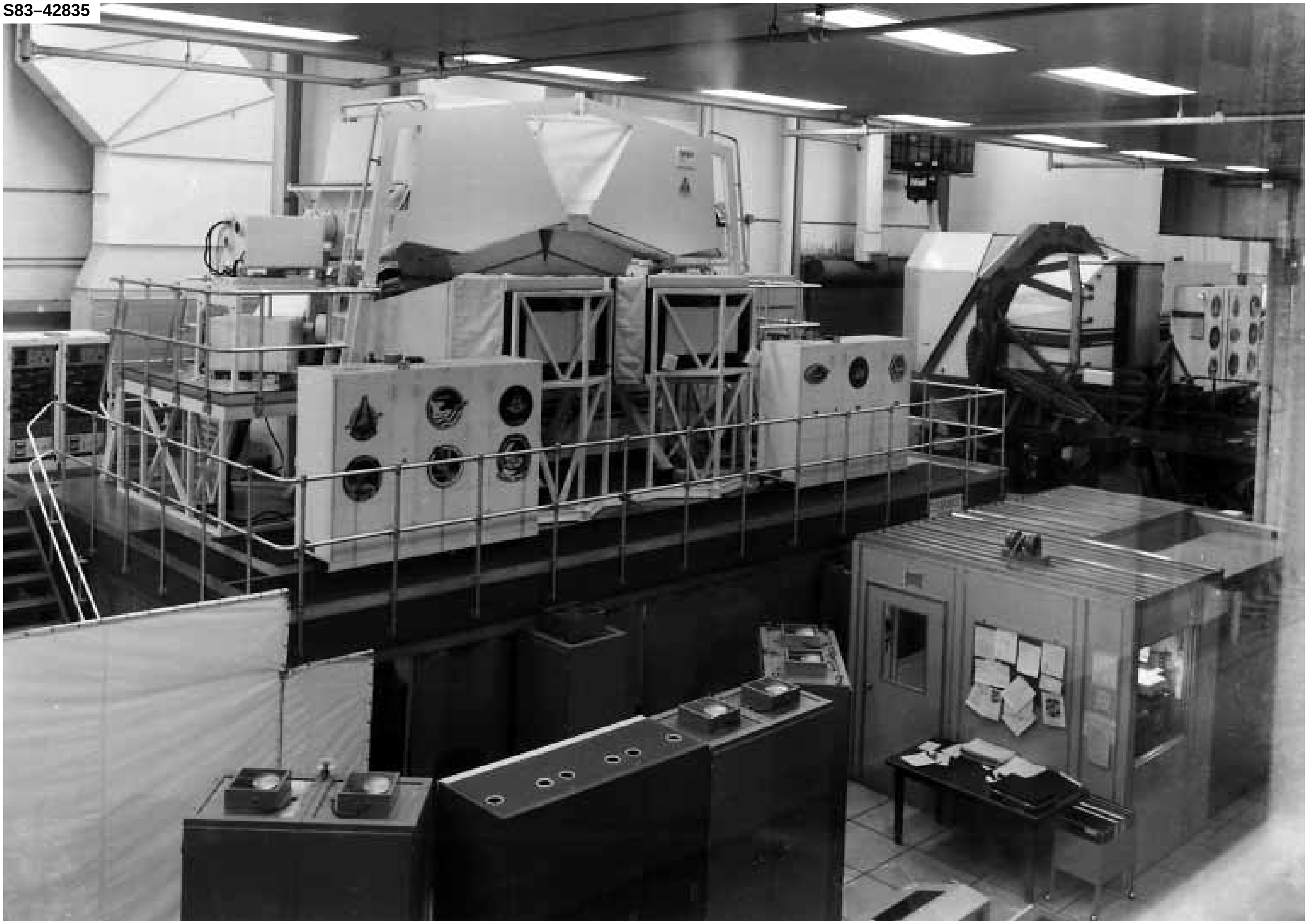

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Figure 2–6. Fixed–base crew station

Ascent and Entry Training in the Motion–Base Simulator

The Motion–Base (MB) simulator is a high–fidelity replica of the shuttle forward flight deck with seating for the four crewmembers on the flight deck. The aft flight deck and middeck are not provided. As with the FB and GNS, all controls and displays are active, and visual and aural cues are provided. As the name implies, the MB provides motion cues essential for an accurate simulation of ascent, deorbit, entry, and landing.

The crew station is mounted on a motion platform assembly with a total of seven hydraulic servo–actuators (figure 2–7) providing six degrees of freedom along with a capability to pitch the crew cabin to simulate the vertical launch position. With the exception of the extended pitch capability, the motion system is similar to those used on other six–degree–of–freedom flight simulators. During launch and for the first 2 minutes of ascent, the crew cabin is pitched up to 90° to simulate the relative g–force direction aligned with the X–axis of the shuttle. The motion cues simulated with this system include vehicle rotation translation and vibration associated with lift–off, Solid Rocket Booster (SRB) tail–off and staging, Space Shuttle Main Engine (SSME) acceleration and cutoff, Orbital Maneuvering System (OMS) and Reaction Control System (RCS) maneuvers, aerodynamic maneuvers, landing, and rollout. Detailed motion system capabilities are listed in table 2–4.

The basic design of the MB is the same as for all other flight simulators. The simulation software controls the motion platform attitude and rates to give the crewmember the perception of vehicle motion. This is accomplished by the simulation software commanding a platform rotation or translation to be perceived by the crewmember as the onset of acceleration; this acceleration is followed by a very subtle motion to return the platform to the neutral position. This subtle motion is constrained to occur at rates below the level of human perception.

The MB is located next to the FB in the high bay area of building 5 (see figure 1–1). Access to the crew station is through a door aligned with the lift platform at the rear of the crew station.

Table 2–4. Motion system capability

Rotation	Excursion, deg	Velocity, deg/sec	Acceleration, deg/sec
Pitch	+28.0	15.0	50.0
	–26.5		
Extended pitch	+80.0	42.1 up	
	–0.0	43.0 down	
Roll	+18.5	15.0	50.0
Yaw	+23.0	15.0	50.0
Displacement	**Excursion, in.**	**Velocity, in/sec**	**Onset accel, g**
Longitudinal	+42.0	24.0	+3
Lateral	+42.0	24.0	+3
Vertical	+36.0	24.0	+4

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Figure 2–7. Motion–base crew station

Visual and Aural Simulations

Visual Capabilities

To provide the necessary visual cues for the high–fidelity simulation provided by each of the three simulators, FB, GNS, and MB, out–the–window and Closed–Circuit Television (CCTV) visual scenes are provided by the computer image generation system. Each of the three simulators has a dedicated visual system. This system is composed of three elements: the image generator, the crew station displays, and the video switching system. The visual system is used to display out–the–window scenes for the forward, aft, and overhead windows, and CCTV scenes from the payload bay or cabin TV cameras. For these scenes, visual models of the shuttle, payloads, RMS, Ku–band antenna, Earth, Sun, Moon, four planets, and the stars are used, as well as live TV camera sources from the flight deck and middeck cameras and video from the other training facilities.

The image generator, an Evans and Sutherland ESIG 3000, is the computer that generates the video to be displayed. The GNS and FB each have two ESIG 3000 image generators to generate all the computer video images used in the forward, aft, and CCTV scenes. The MB has one image generator for the forward displays only.

The crew station displays are composed of three different types of devices. These devices are Wide Area Collimated (WAC) displays, CCTV monitor displays, and combination projector/pancake window displays. The WAC displays are used for the six forward windows in the forward flight deck. The CCTV monitors are located in the aft flight deck. The projector/pancake window displays are used above and behind the aft flight deck to simulate the scenes out of the aft and overhead windows. These different displays are used to satisfy different field–of–view and resolution requirements. The aft overhead windows have a very large field–of–view requirement to accomplish the training associated with RMS and payload deploy training. The forward windows have the brightness and resolution to satisfy the approach and landing requirement. The CCTV monitors have the requirement to match the flight equipment's characteristics.

The video switching system is used to route the video from the image generators or live TV sources to the crew station displays and to MCC, as well as to video monitors at the IS and OS. The capability to record the forward and CCTV video scenes on VHS video tape is also provided at the IS.

During training sessions, the following simulated events are represented in the visual. For launch and ascent training, the view from the shuttle on the launch pad, SRB ignition and burn, SRB separation, forward RCS jet firing plumes, and a model of the External Tank (ET) are provided. For on–orbit training, the forward, aft, and overhead window views of the Earth, Moon, stars, and payload bay, including models of the payload, payload bay doors, RMS, Ku–band antenna, RCS, and OMS plumes are provided. For entry and landing training, out–the–window views of the Earth, including a detailed model of the landing site and all shuttle approach and landing aids, are provided. For all phases of flight, all vehicle rotations and translations and all day/night and payload bay light effects are represented in the visual scenes.

Aural Cue Capabilities

Aural cues are provided in all simulators to simulate the expected cockpit environment for both nominal and off–nominal events. The aural cues simulated include the sounds from the main engines, the SRB burn, the forward RCS jets, the cabin fan, the ET separation pyro, the landing gear deploy pyro, the ground contact, the rollout, and the cabin leaks.

Additional Capabilities of the SMS

SMS Integration With the WETF

Audio and visual connections between either the FB or GNS allow for integrated EVA training in the SMS/MCC/WETF environment. The audio is realistically simulated, allowing CAPCOM to communicate with the EVA crewmembers and the orbiter crewmembers. The visual system allows the video from the WETF to be controlled and viewed using the CCTV system. The WETF, located in building 29, provides controlled neutral buoyancy in water to simulate the condition of null gravity. The WETF is an essential tool in the design, testing, and development of spacecraft and crew equipment; in the evaluation of body restraints and handholds; in the development of crew procedures; and in the determination of extravehicular capabilities and workload limits. For the astronaut, it provides important preflight training in becoming familiar with planned crew activities and with the dynamics of body motion under weightless conditions.

The WETF consists primarily of an underground pool that has standard filtering, chlorinating, and pumping systems. Additional systems that support test activities include diving equipment, an environmental control system, a CCTV system, a communications system, an overhead crane system, and medical support facilities. The full–scale mockup of the orbiter can be placed in the facility. Power for the lights and other instrumentation is provided with voltages of 115 and 208 V ac. Shop air is available for operation of air tools. Some of the systems used within the WETF are the RMS, Environmental Control System (ECS), communications (COMM) system, ballast system for pressure–suited operations, and the CCTV.

The WETF provides male and female divers who ensure crew safety, as well as a medical station for immediate response in the event of an emergency. Figure 2–8 simulates a diver working with a crewmember during an EVA training exercise. The current design of the WETF is shown in figure 2–9.

Integrated SLS

The GNS or FB can integrate with the SLS to provide integrated orbiter/Spacelab systems training. The SLS/SMS is also capable of integrating with the Payload Crew Training Complex (PCTC) at Marshall Space Flight Center (MSFC). The SLS is located in building 5 and has a flight crew training area (figure 2–10) and an IS similar to all other SMS ISs (figure 2–11). The IS is separated from the flight crew training area by a door that provides easy access to the instructor by the crew.

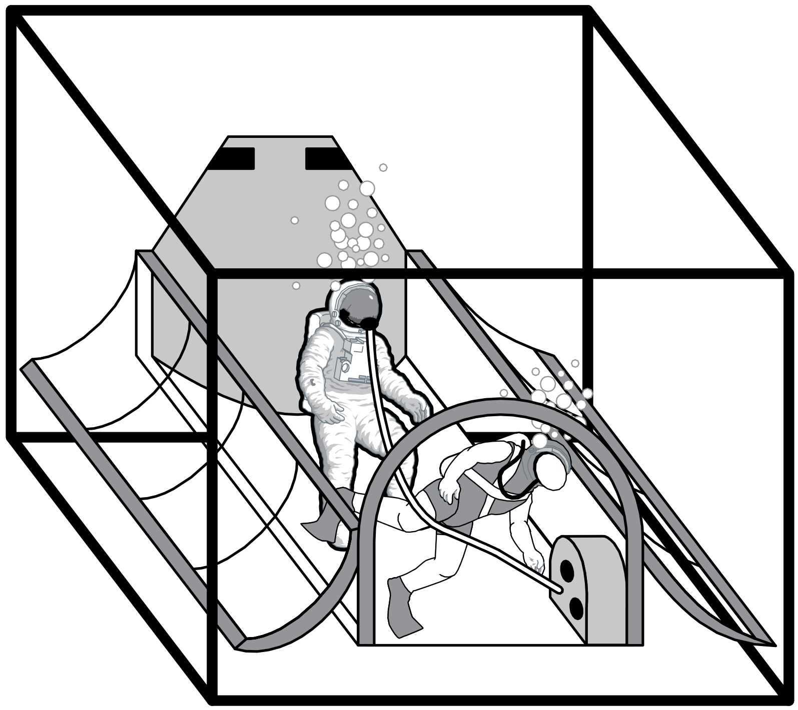
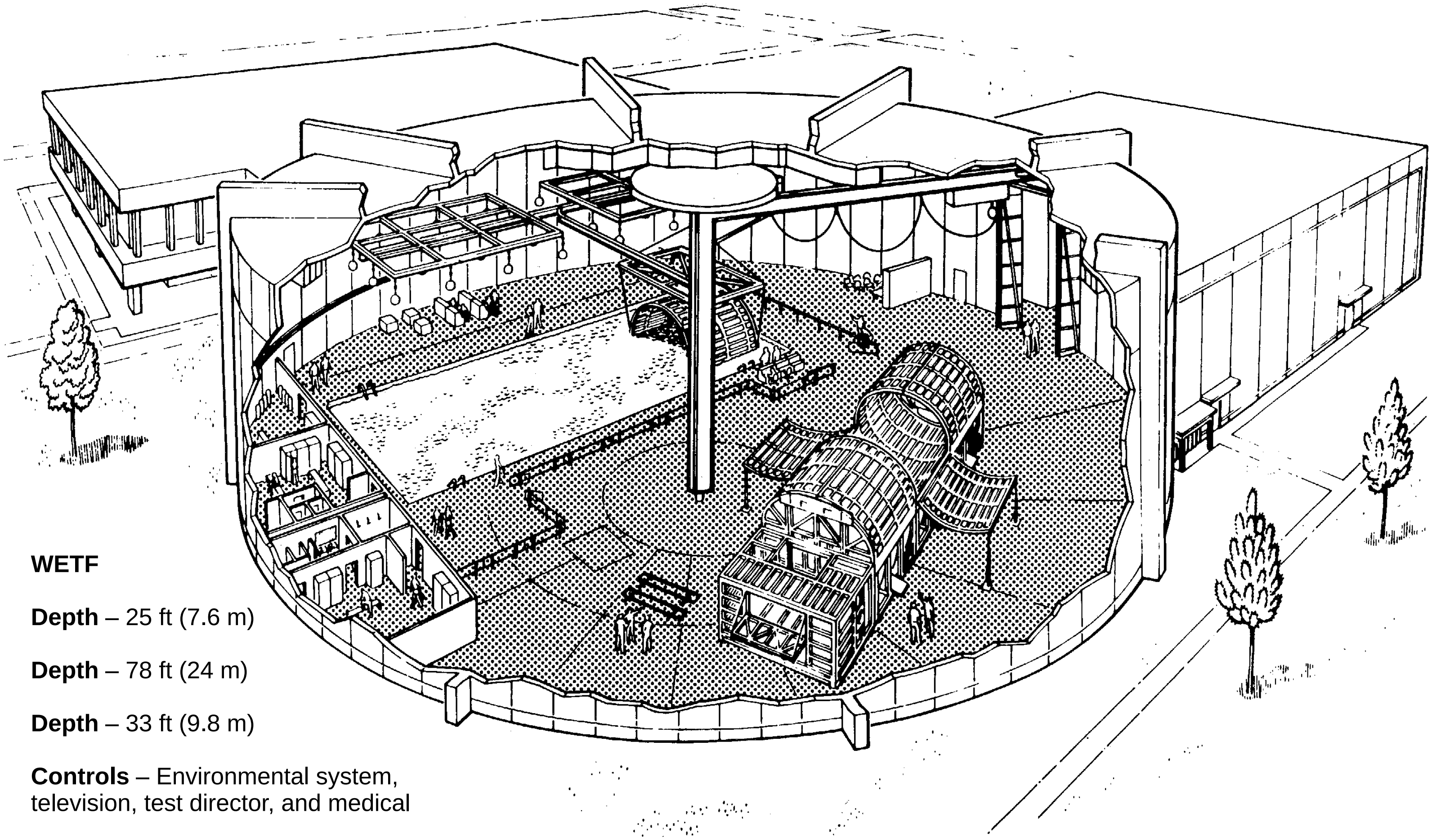


Figure 2–8. Weightless Environment Training Facility (WETF)



WETF

Depth – 25 ft (7.6 m)

Depth – 78 ft (24 m)

Depth – 33 ft (9.8 m)

Controls – Environmental system, television, test director, and medical

Cranes – 5–ton (4.5 metric ton) pneumatic hoist on monorail and 6.6–ton (6 metric ton) circular pneumatic hoist

Purification system – Standard filtering, chlorinating, and pumping

Water temperature – 92° F (33° C)

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Figure 2–9. WETF overview

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Figure 2–10. Flight crew training area

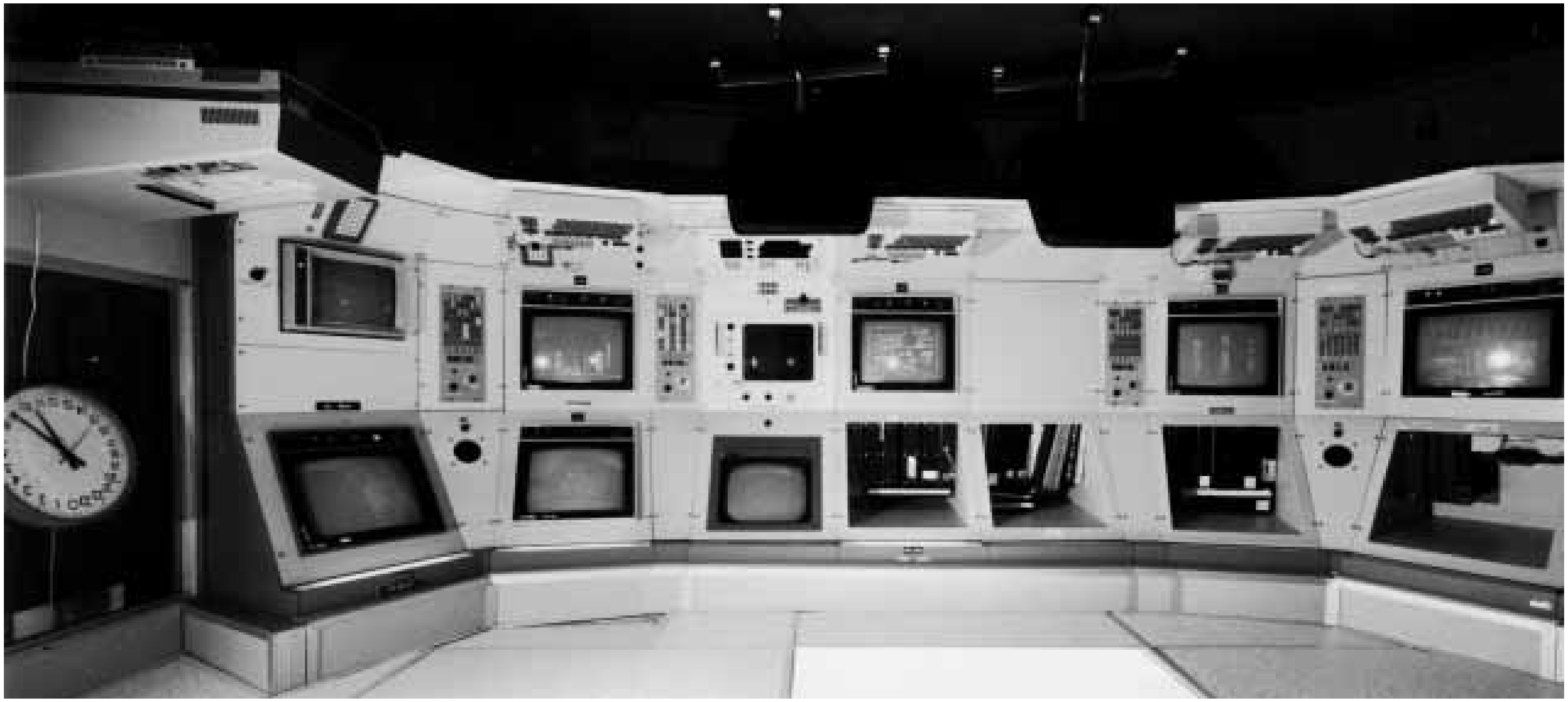


Figure 2–11. SLS instructor station

Section 3
Instructor and Operator Stations

The GNS, FB, and MB each have one IS and one OS. The FB and MB ISs are located in separate rooms off the main hallway in building 5, and the GNS IS is located in a room adjacent to the GNS in building 35. The OSs for each simulator are colocated with each simulator in buildings 5 and 35.

Instructor Stations

The ISs provide the controls and displays necessary to effect crew training. There are teams of SMS instructors, each assigned to train a different flightcrew. Each team consists of the following five positions: control instructor, navigation instructor, communications instructor, systems instructor, and team lead. In addition to the assigned team of five instructors, specialist instructors for payloads, RMS, rendezvous, ascent, and entry procedures also provide training in their respective areas of expertise. During simulated sessions at the SMS, the instructors' jobs include monitoring crew actions and procedures; noting incorrect actions and areas where more work is needed; assisting in the development of pilot techniques for flying the orbiter; activating malfunctions according to a script or through real–time coordination with the team lead; answering crew questions in the areas of the instructor's specialty; and, as MCC flight controllers, making simulated ground calls to the crew during nonintegrated simulations.

The ISs provide the capability to display, monitor, and control system status, switch positions, and flight environment (e.g., wind speed and direction, barometric pressure, air temperatures). Figure 3–1 is a picture of the FB IS. Each IS has nine Aydin Alphanumeric (A/N) Cathode–Ray Tubes (CRTs), five graphics CRTs, four cross–display CRTs which mirror the crew station CRTs, four keyboards, seven digital voice intercommunication system (DVIS) control heads for voice communication with the crew and other instructors, three color TV monitors of the simulated visual scenes (one monitor in the MB IS for the forward visual only), a hardcopy machine for the Aydin and one for the graphics CRTs, and a CRT that monitors mission event times.

Displays can be placed on Aydin and graphics CRTs from any one of the four keyboards, but only one assigned Aydin can be controlled interactively by each keyboard. The interactive Aydin is used for malfunction insertion, switch reconfiguration, system status, and flight environment changes. The SMS has a capability of approximately 6800 malfunctions, discrete and variable, which can be activated manually or automatically.

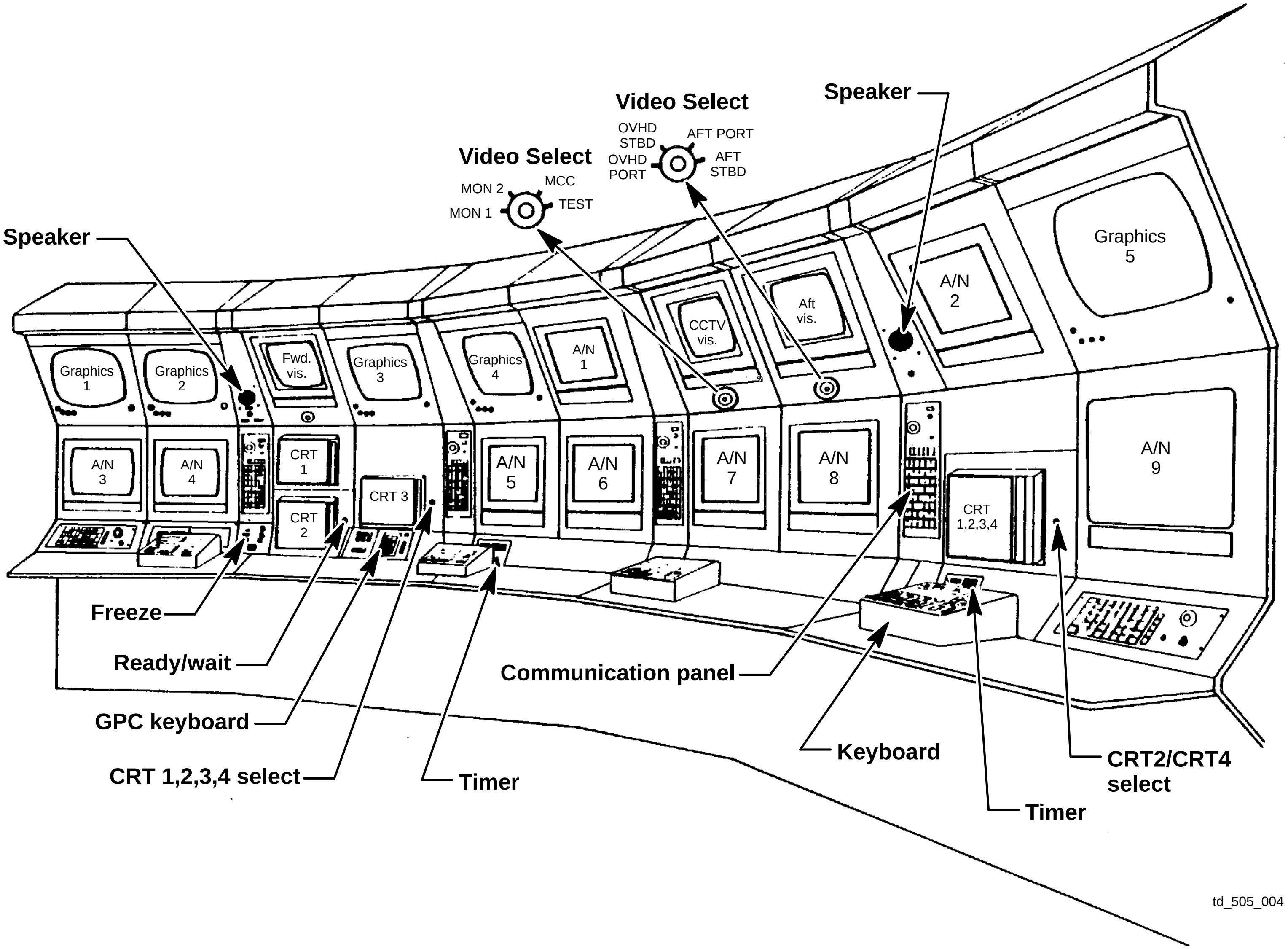


Figure 3–1. Instructor station

Operator Stations

The OSs provide the controls and displays necessary to prepare the simulators for the training sessions and to operate the facility during the training sessions. The OSs for the two crew stations have identical controls and displays except that the MB OS also has controls and status indicators dedicated to the motion system.

In addition to controlling the operation of the SMS itself, the operator has the responsibility of preparing the simulators for each session. This includes entering “look and enters” which initialize quantities such as consumables and pressures, setting the visual system, and configuring the system to the chosen reset point. The SMS has a standard set of reset points that correspond to different phases of a flight. Thus, training for discrete phases of a flight can be accomplished by resetting the simulator to the appropriate start point. If any quantities that are defined by the reset point are not appropriate for the run, the operator can type in the correct data using the interactive CRT. The time required for a complete reset is about 4.5 minutes.

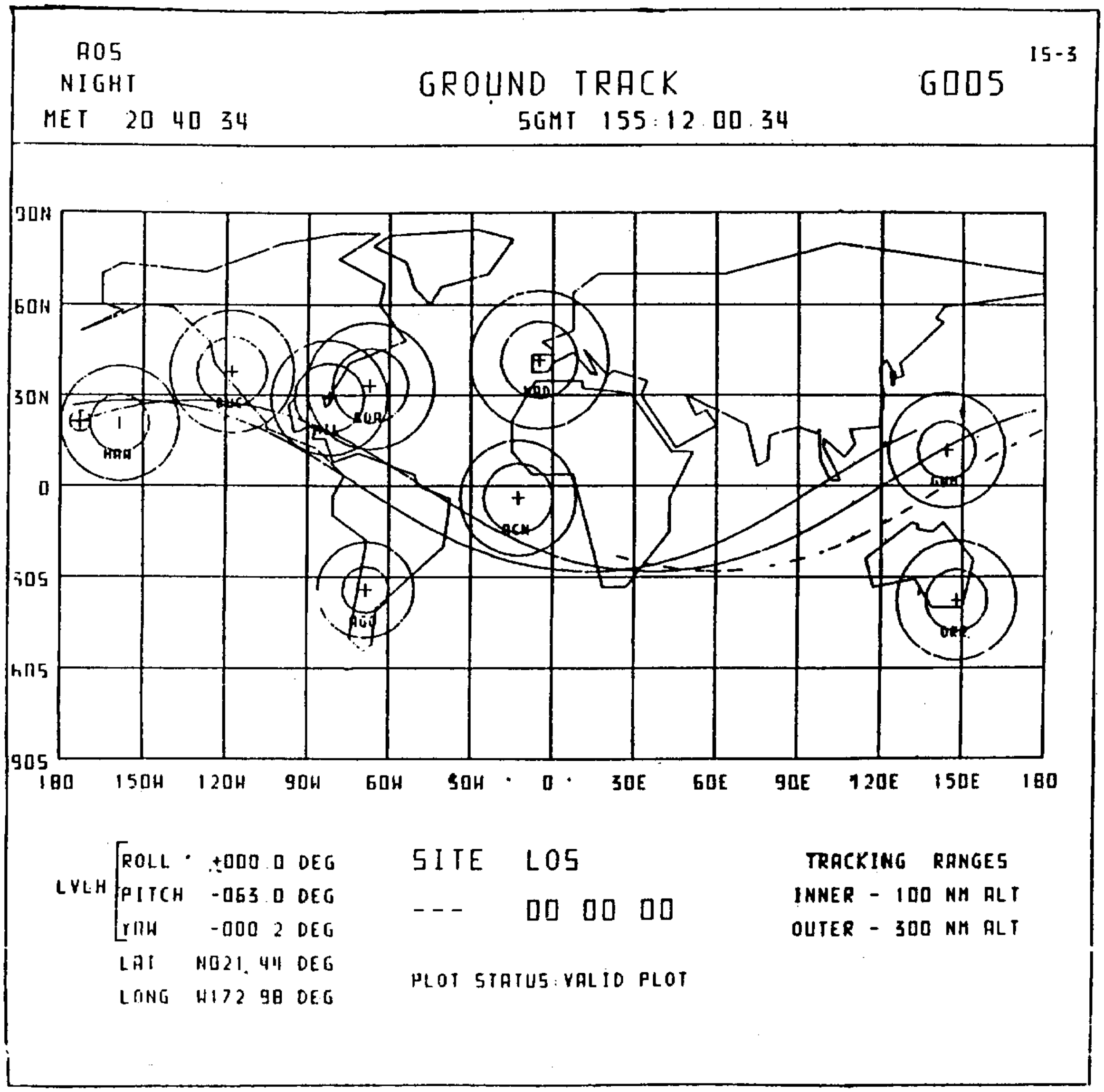
There are four other control modes to the SMS in addition to the reset mode. The “run mode” means that the simulation is underway. The “data store” mode allows the SMS to record data to create a new simulation start point. In the “freeze” mode, the simulation has stopped. The freeze mode can be activated at both the OS and the IS and follows the reset mode. The “step–ahead mode” allows the SMS to step ahead to a specific point in time. The simulation control modes are activated by the operator upon request by the team lead.

Displays

Four separate types of CRT screens are used on the IS console to display SMS data and to allow control of simulation system models. These screens consist of flight–type CRTs, TV monitors, Aydin A/N screens, and graphics screens such as those shown in figure 3–2. The types of displays available on each screen and their usage are described on the following pages.

Graphics Displays

The displays on the graphics screens provide a pictorial representation of information only and are not interactive. When requesting one of these displays, you must have a graphics (G1, 2, 3, 4, 5) screen currently selected on the keyboard. Otherwise, an error message will flash on the right–hand side of the interactive line. Figure 3–2 is an example of a graphics display.



td_505a_019

Figure 3–2. Graphics display showing orbiter groundtrack

Flight–Type CRTs

The four flight–type CRTs (figure 3–2) provide the instructor repeaters of the crew station CRTs, allowing the onboard displays to be monitored. Three are grouped together near the left end of the station, and the fourth is near the right end. In the group of three, the upper left CRT shows the display called up on CRT 1 in the crew station, and the lower CRT presents the CRT 3 display. The right–hand CRT in the group is selectable between the CRT 2 or CRT 4 display (only in FB IS) using the rotary select to the right of the CRT. The far right CRT is selectable to CRTs 1, 2, 3, and 4 using the rotary select to the right of this CRT.

TV Monitors

Three TV monitors allow the instructor to view the visual scenes available to the crew. The three monitors are located on the upper portion of the instructor console. The leftmost monitor shows the instructor the scene the crew sees in the forward windows if the forward visuals are active. The middle screen is selectable so that the instructor can display the visual scene the crew has selected on the crew station CCTV monitors 1 and 2 or for downlink to the MCC. The test position is for maintenance purposes only. The rightmost monitor is selectable to the various aft crew station window visual scenes if the aft visuals are active.

Aydin A/N Displays

The major portion of displays available to an instructor will be displayed on the nine Aydin screens. These displays include menu pages, crew station panel repeater pages, systems status and control pages, and special operations and configuration pages. There are also operator pages that are normally not available to the instructor and, therefore, will not be discussed in this text.

Each page displayed on the Aydin screen provides a standard header as shown in figure 3–3. The data provided include the simulated status of

1. Acquisition of Signal (AOS) or Loss of Signal (LOS)
2. Simulated night or day
3. Mission Elapsed Time (MET) in hours and minutes
4. Simulator status RUN, freeze (FRZ), step ahead (STEP), and reset (REST)
5. Simulated Greenwich Mean Time (SGMT)
6. Instructor Operating Station (IOS) controller status up when running or blank when not
7. Page name and mnemonic

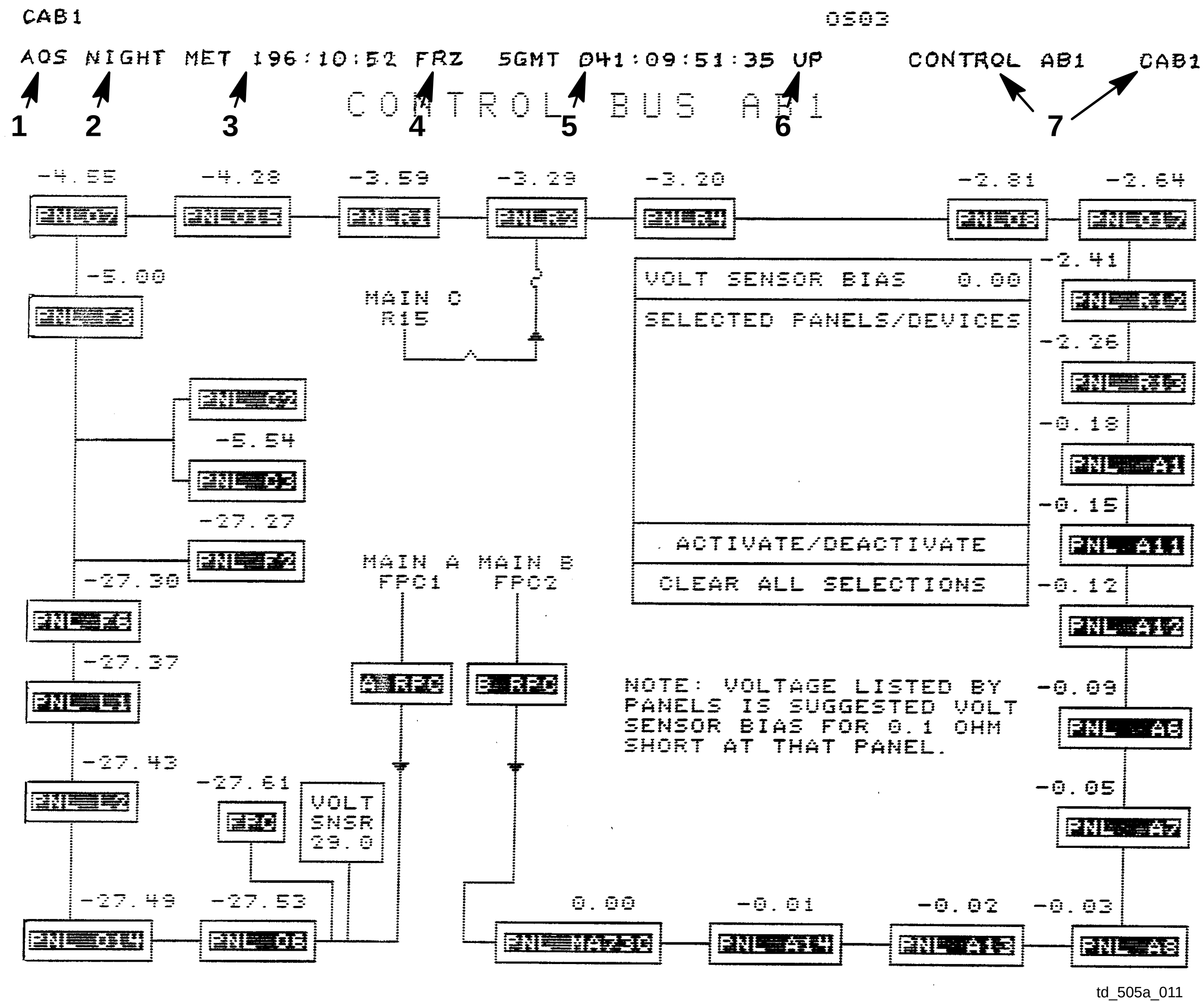


Figure 3–3. Standard header

Simulation Control Area

The Simulation Control Area (SCA), located in room 3301 on the third floor of building 30 south (MCC), monitors, controls, and coordinates the integrated simulations. During those simulations, the SCA is manned by an instructor team which directly monitors the performance of the flight control team. (See figures 3–4 and 3–5 for the SCA positions.) In addition, the SCA personnel are responsible for planning the individual simulation sessions, preparing the simulation scripts that contain the malfunctions to be entered, and debriefing the flight controllers and the crew. There are up to five teams of SCA instructors, each headed by a simulation supervisor who directs the simulation sessions.

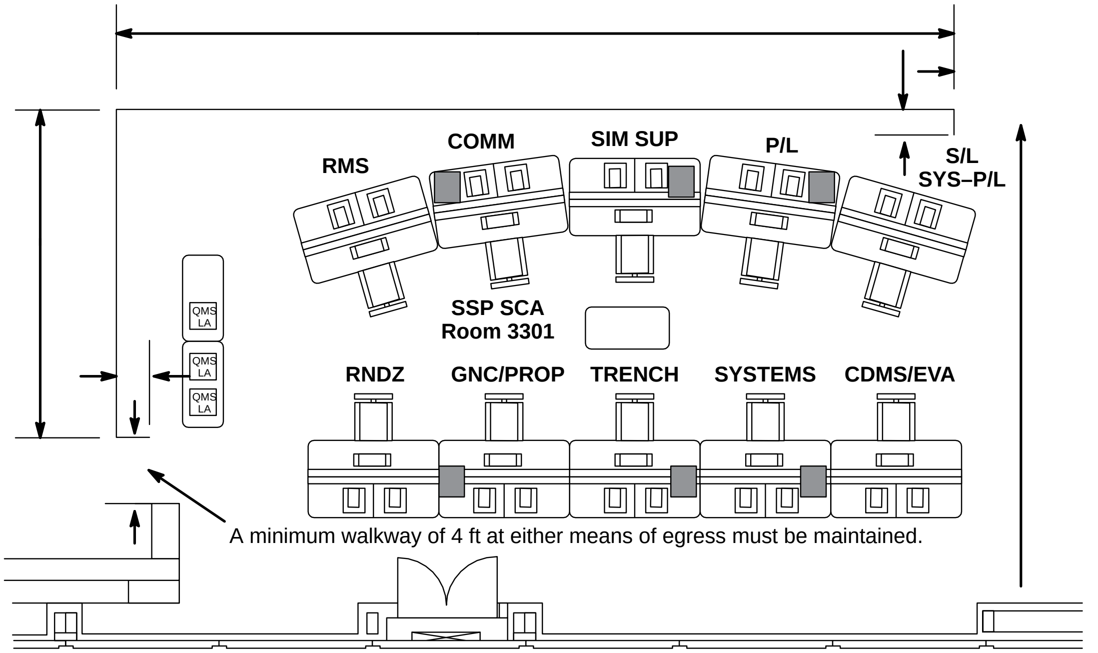


Figure 3–4. Layout of simulation control area for orbit

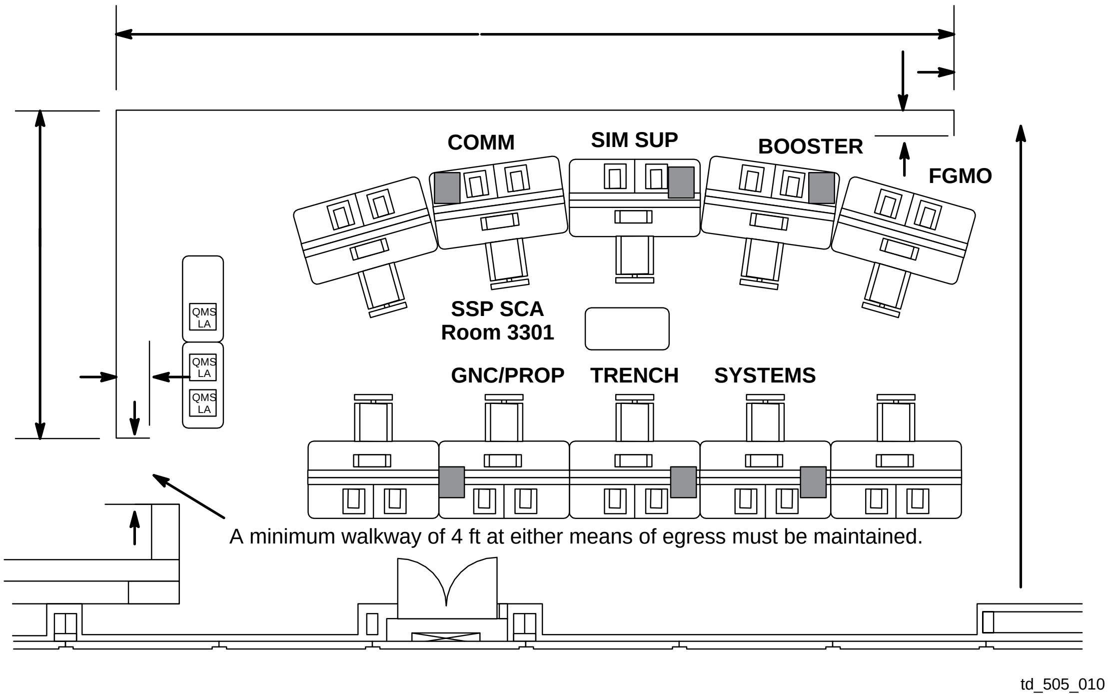


Figure 3–5. Layout of simulation control area for ascent or entry

Section 4
Components of the SMS

Computer Complex

The SMS digital computer facility occupies most of the floor space of the high bay area in building 5 (figure 1–1). The GNS computer complex is located in building 35, supporting only the GNS. It has the capability to serve the FBCS and MBCS simultaneously. The complex consists of the following interconnected computers:

Computers (25)

Concurrent Computers

3280:11	–	BIC (3), MTM 5, MTM 35, SLSU,
	–	NSSU (2), SID test bed, TB (2)
3260:6	–	PLS (3), MIC (3)
3250:1	–	Batch
SLS 6400	–	Motion monitor workstation

Alliant Computer

FX/80	–	Project Burke

Motorola Controller

IBC:4	–	EMIC, FMIC, GMIC, and test bed

Networks (8)

BURKE	–	Validation, logging, diagnostics
ENET1	–	NSSU, hosts, print server
ENET2	–	Tape silo, MTM, MMUs, G host, DCPs
ENET3	–	SPF
SCRAMNAT	–	MICs/Alliant
VISUAL LAN	–	IG, computers
RT LAN	–	RTSC/OSS computers
GP LAN	–	Development

Peripherals (166)

Disk Drives

RSD 80 mbyte	–	45
300 mbyte	–	3
80 mbyte	–	9
1.2 gbyte	–	12

Line Printers

Data Products	–	13
Fujitsu	–	1

Tape Drives

STC	–	7
Telex	–	5
Wanco	–	12

Monitors

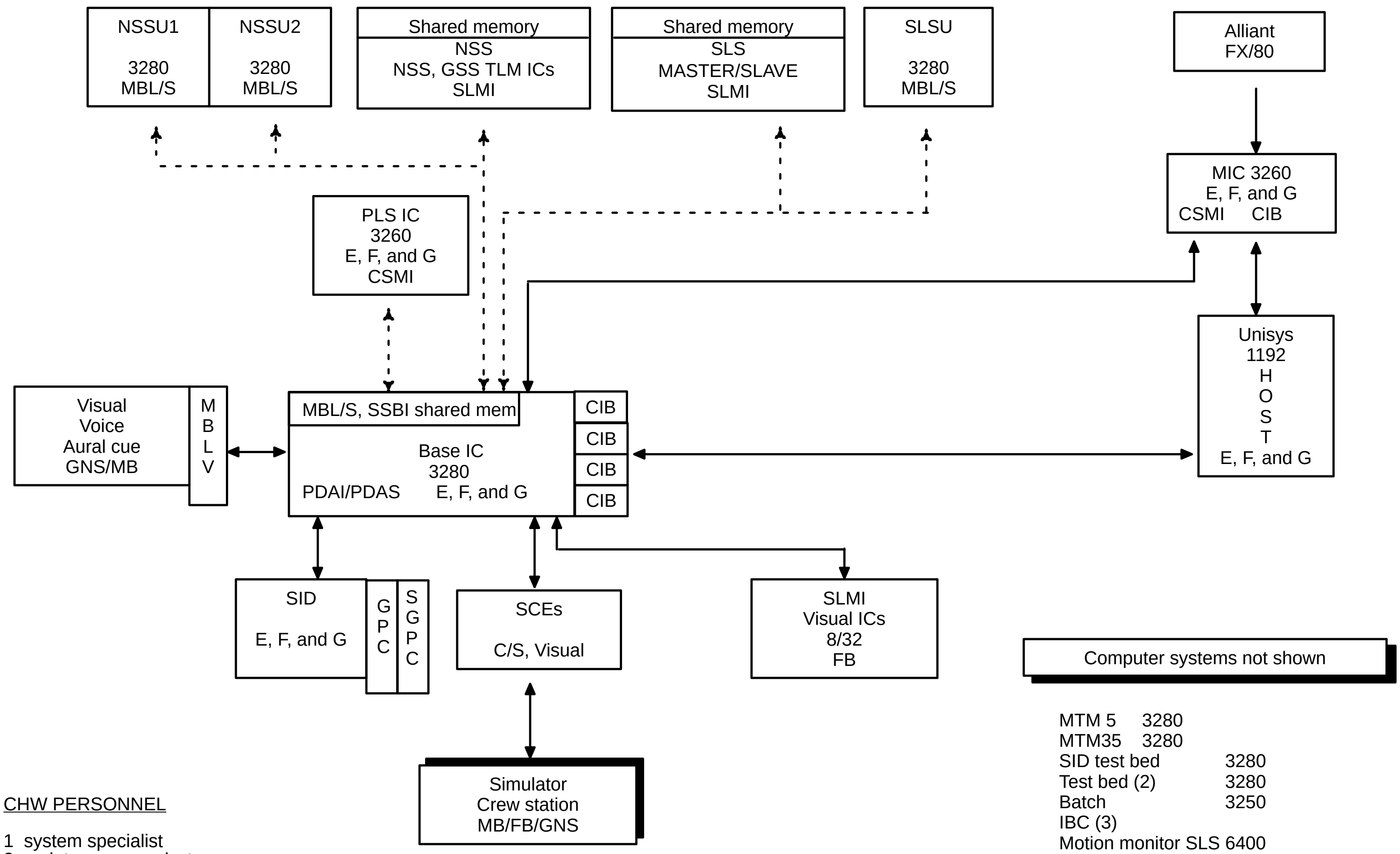
System Consoles	–	47
X–windows	–	12

Host Computers

The host computers are three large–scale UNIVAC 1100/92 computers, which contain the majority of the simulation math models. Each computer is in a two by two configuration, with two Instrumentation Processors (IPs) and two Input/Output Processor (IOP) units. The UNIVAC 1192 is capable of executing an average simulation mix at approximately 5 million operations per second. One computer is assigned to each crew station (FBCS, MBCS, and GNS crew station).

Support Computers

The concurrent support computers consist of seventeen 3260 (6) and 3280 (11) minicomputers, which gather and transfer data as well as house the math models for tracking, telemetry, and communication simulations. The execution capability of the 3260/3280 is approximately 2 to 4 million instrumentations per second (MIPS). However, the input/output and computational capabilities of these units are not identical and vary according to the task performed. As figure 4–1 shows, all 17 intelligent controllers (ICs) interface with each other and with the



CHW PERSONNEL

1 system specialist
3 maintenance analysts
4 field engineers
6 technicians
1 technician assistant

Figure 4–1. Computer hardware layout

IL_6

host computers by transferring commands for flight control and other functions, sensor signals, shuttle position and status, and other quantities required for simulation.

Simulation Interface Device and Intelligent Controller and General–Purpose Computers

The Simulation Interface Device (SID) houses the flight GPCs for the three crew stations and data–handling equipment that interface with the SID IC. The base IC contains the reset points, data storage, and applications software for the launch processing system. The SID models the performance of various peripheral devices onboard the orbiter, such as the Multiplexer/ Demultiplexers (MDMs).

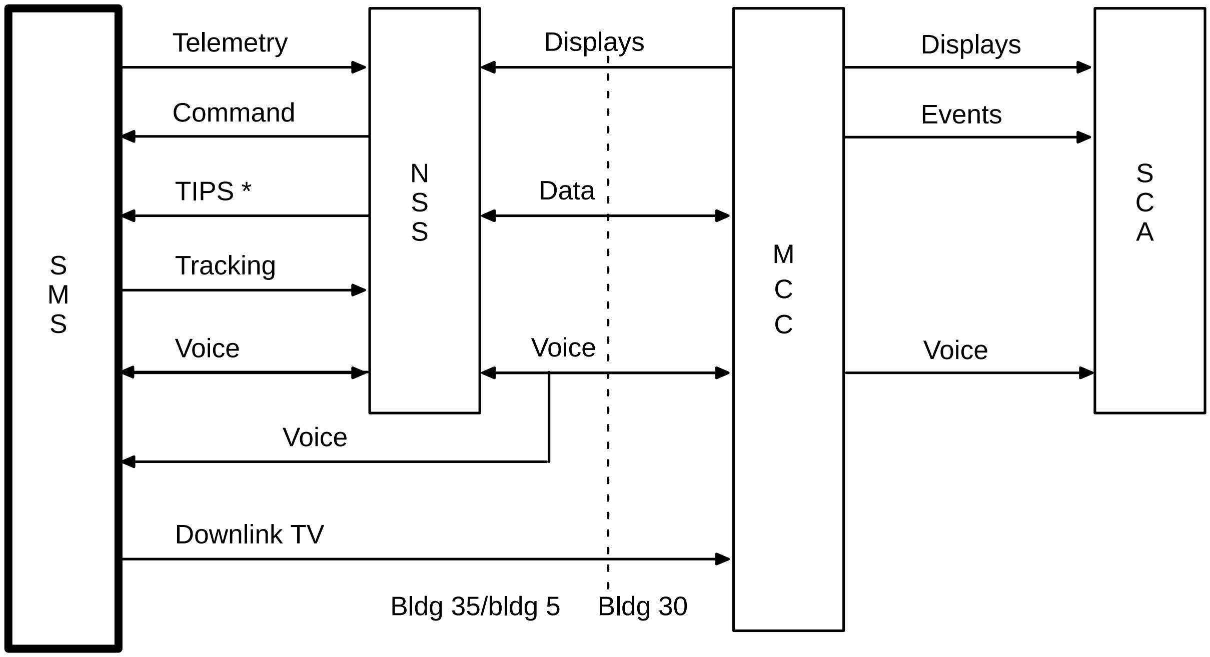
Real GPCs are used in the SMS so that the Flight Software (FSW) used during actual space shuttle missions can be exercised during flightcrew training. The GPCs are IBM AP101S computers, which carry out all the required data processing functions onboard the vehicle (e.g., flight control, malfunction detection, redundancy management, etc.). The AP101S is a high–performance flight computer with memory error–correcting logic capable of processing approximately 1 MIPS. The only real difference between the AP101S computers used in the SMS and those flown on the actual vehicle is that the ground units used in the SMS are not subjected to the rigorous “flight certification” testing required of the units that fly on the vehicle; functionally they are the same.

The GPCs used in the SMS are physically located in the SID, and it is through the SID that the input/output data from the GPCs interface with the models that are resident in the base IC and UNIVAC host computers.

Network Simulation System

The NSS provides the voice and data link between the MCC, the Payload Operations Control Centers (POCCs), and the SMS during integrated simulations. The computers, NSS OS, and NSS ISs are located in building 5 along with the rest of the SMS facility. (See figure 1–1.) The voice and data link between the three simulators, their respective ISs, and the MCC are all hardwired. It is only through the NSS that the simulators can be tied to the MCC, the POCCs, and any other remote sites. The NSS simulates both the Ground Spacecraft Tracking and Data Network (GSTDN) and the Tracking and Data Relay Satellite System (TDRSS).

See figures 4–2, 4–3, and 4–4 for diagrams of the communications flow, the integrated simulation configuration, and the joint integrated simulation configuration, respectively.



* Only on joint integrated simulations/flight–specific orbit simulations.

Figure 4–2. Communications flow

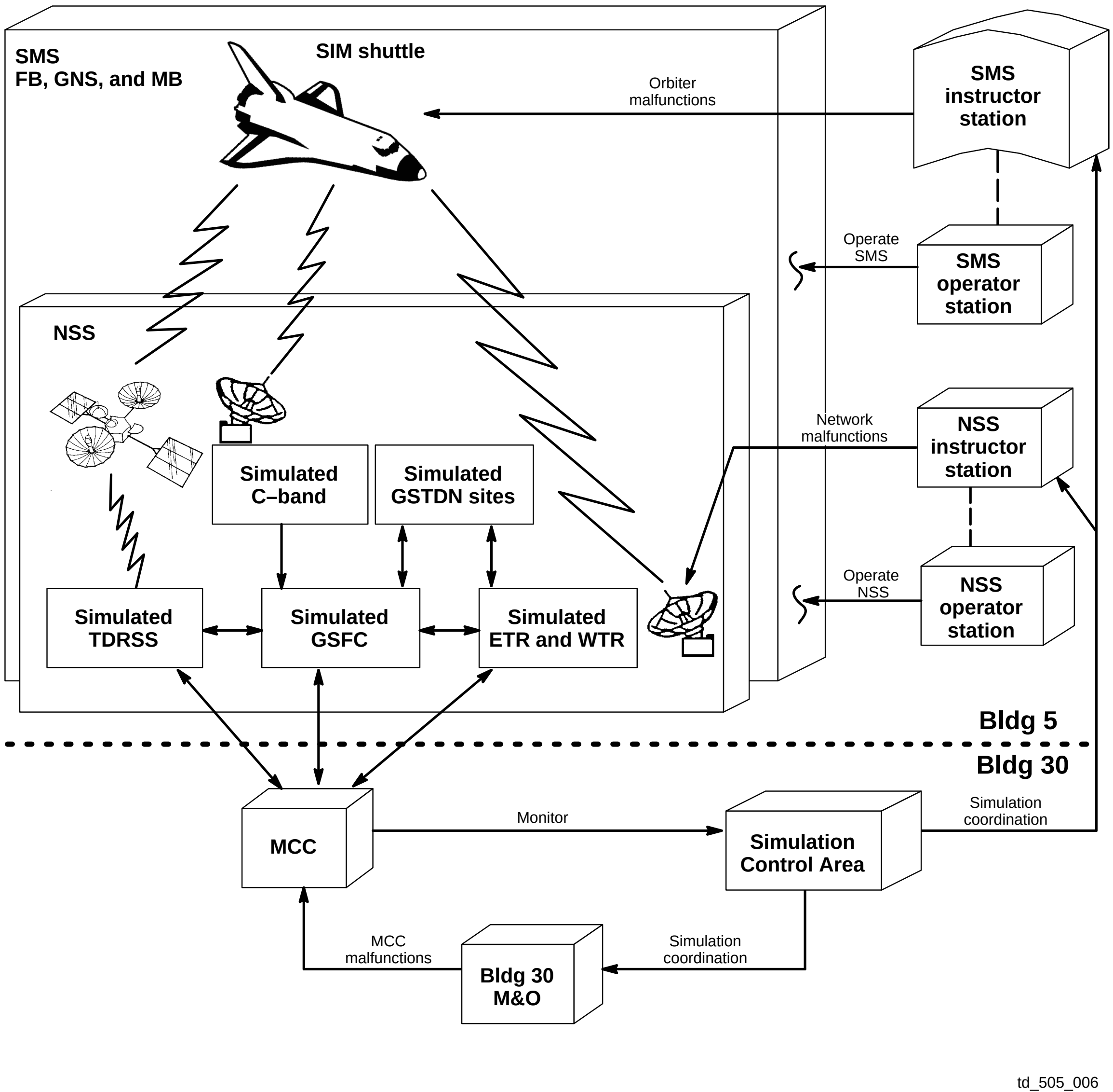


Figure 4–3. Integrated simulation network

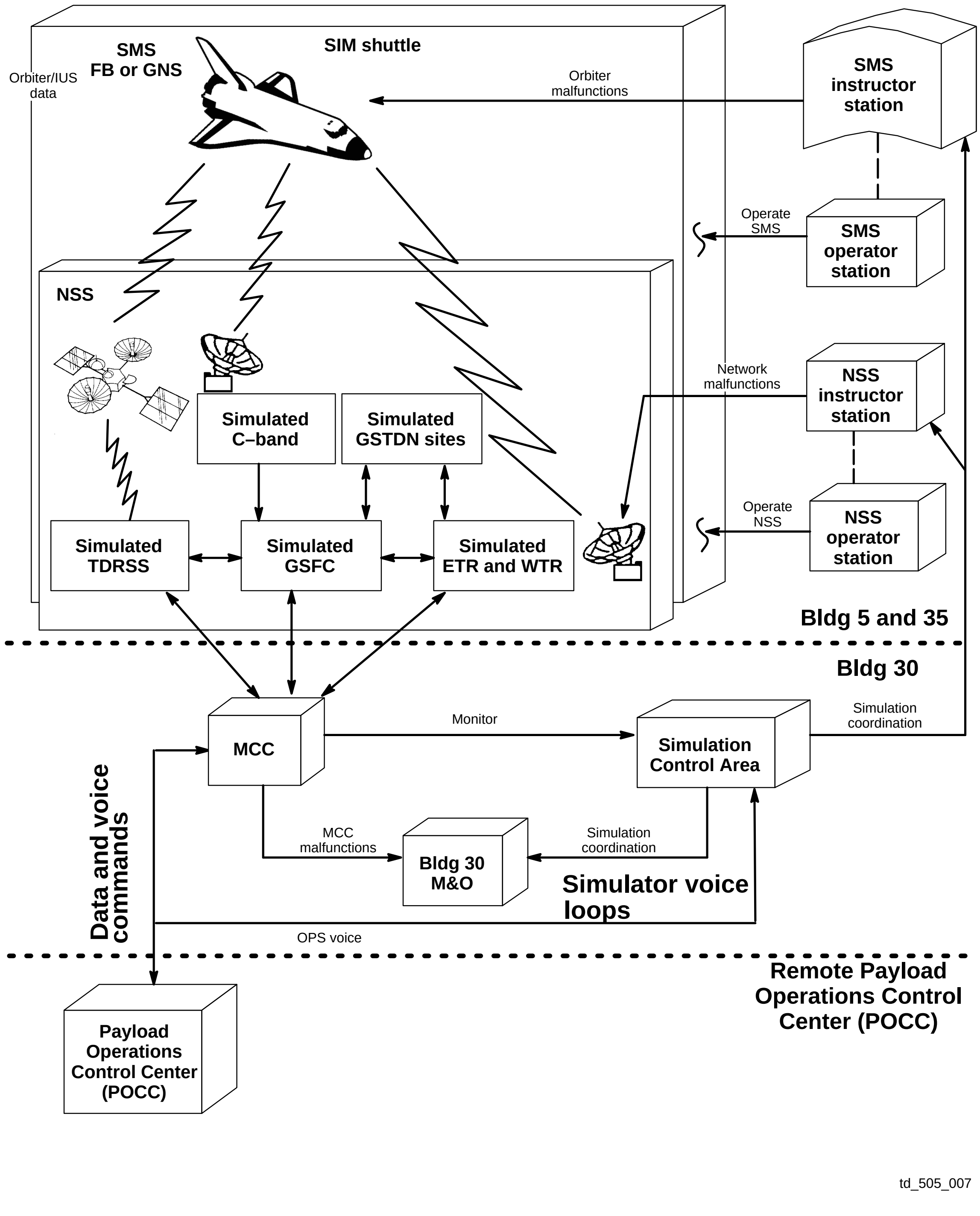


Figure 4–4. Joint integrated simulation network

Conclusion

The SMS represents a major advancement in mission simulators in terms of fidelity and completeness. It uses flight cockpit hardware, computers, and software that enable the SMS to simulate as closely as possible the actual vehicle. The ability of the simulator to perform integrated simulations with the MCC, SCA, and POCCs allows for the simultaneous training of flight controllers and crews in a simulated flight environment. The SMS will be a major training device for the manned space program for the next 2 decades.

Appendix A
Acronyms and Abbreviations

A/N	Alphanumeric
AFGMO	Ascent Flight Guidance Procedure Monitor
AOS	Acquisition Of Signal
CBT	Computer–Based Training
CCT	Crew Compartment Trainer
CCTV	Closed–Circuit Television
CDMS	Command and Data Management Subsystem
COMM	Communications
CRT	Cathode–Ray Tube
DPS	Data Processing System Dynamics
DYN	Dynamics
EFGMO	Entry Flight Guidance Procedure Monitor
ET	External Tank
ETR	Eastern Test Range
EVA	Extravehicular Activity
FB	Fixed Base
FBCS	Fixed–Base Crew Station
FDF	Flight Data File
FFT	Full Fuselage Trainer
FGMO	Flight Guidance Monitor
GNC	Guidance Navigation and Control
GNS	Guidance and Navigation Simulator
GPC	General–Purpose Computer
GSFC	Goddard Space Flight Center
GSTDN	Ground Spacecraft Tracking and Data Network
IC	Intelligent Controller
IS	Instructor Station
IUS	Initial Upper Stage
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
LOS	Loss Of Signal
LVLH	Local Vertical Local Horizontal
MB	Motion Base

MBCS	Motion–Base Crew Station
MCC	Mission Control Center
MDF	Manipulator Development Facility
MET	Mission Elapsed Time
MIPS	Million Instrumentations Per Second
NASA	National Aeronautics and Space Administration
NSS	Network Simulation System
OMS	Orbital Maneuvering System
OS	Operator Station
P/L	Payload
POCC	Payload Operations Control Center
PROP	Propulsion
RCS	Reaction Control System
RNDZ	Rendezvous
RMS	Remote Manipulator System
SCA	Simulation Control Area
SESF	Shuttle Engineering Simulator Forward Station
SID	Simulation Interface Device
SIM SUP	Simulation Supervisor
SLS	Spacelab Simulator
SL SYS	Spacelab Systems
SMS	Shuttle Mission Simulator
SPPF	Spacehab Payload Processing Facility
SRB	Solid Rocket Booster
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SST	Single–System Trainer
STC	Satellite Test Center
TACAN	Tactical Air Command and Navigation System
TDRSS	Tracking and Data Relay Satellite System
TIPS	Thermal Impulse Print System
TSS	Telemetry Simulation System
UHF	Ultrahigh Frequency
W/S	Workstation
WAC	Wide Area Collimated
WCS	Waste Collection System
WETF	Weightless Environment Training Facility
WTR	Western Test Range